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Indirect Construction of Hedonic Price Indexes: Empirical Evidence for Private Properties in Switzerland

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INDIRECT CONSTRUCTION OF HEDONIC PRICE INDEXES: EMPIRICAL EVIDENCE FOR PRIVATE PROPERTIES IN SWITZERLAND

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Abstract

This paper analyzes the construction of price indexes for condominiums and single family houses in Switzerland over the period 1985 to 2004 using the indirect method. We find, that the pooling of the data, i.e. direct indexes with fixed hedonic prices, are good models for average properties but can be biased for the indexation of non-average properties. Therefore indirect index construction using predictions for specific properties based on annual equations are recommended.

Based on differentiation of forty regions it is shown, that indexes vary from region to region, but show a comparable general course between 1985 and 2004. In recent years prices for single family houses raised in the large urban areas and tourist resorts but, due to big land reserves, were stable ore even declined in smaller urban and semi-urban as well as in rural areas. Price paths for condominiums are generally comparable to those of single family houses with the big difference, that over the last three years prices were raising in most of the regions.

JEL Classification Codes: C31, R31.

Keywords: Hedonic price, private property, direct index, indirect index, Switzerland.

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1 INTRODUCTION

In recent years hundreds of articles on hedonic models for private properties and index construction have been published (for recent reviews and meta-analysis see for example SIRMANS, MACPHERSON and ZIETZ, 2005; NELSON, 2003; MALPEZZI, 2002 or MAURER, PITZER and SEBASTIAN, 2000).[1] A large part of the literature is based on the analysis of price paths or in a cross-section view on specific effects like the influence of airport noise, infrastructure projects, and other influences on real estate prices.

For modelling the price paths several methods are used in literature. Popular but little quality adjusted and therefore susceptible for biases is the indexation of mean or median prices of sold properties. Recommended are repeated sales methods, since the changes of the prices of the identical property are compared. However the problems of ageing and the declining condition or the consideration of refurbishments remain a challenge. In addition, in markets like Switzerland with a very small turnover rate of the properties the use of the repeated sales method is hardly possible since data is simply not available.

Therefore the hedonic method is very popular and widely used in the literature since it allows the description of a quality adjusted price paths of properties using comparables. For Switzerland several studies applying the hedonic method on private properties have been published in the recent years, like the studies of SALVI, SCHELLENBAUER and SCHMIDT (2004), SCOGNAMIGLIO (2000), HOESLI, FAVARGER and GIACCOTTO (1997), BIGNASCA ET AL. (1996) and BENDER, GACEM and HOESLI (1994) are known. These studies have in common the use of the *direct* hedonic method for the construction of price indexes, i.e. the pooling of the data over the entire observed period and the use of – regionally differentiated – dummy variables for the change of the index over time. The *indirect* method, the estimation of hedonic models on a year to year basis and the indexation of the predicted values of standard objects is rarely used in literature.[2]

The main difference between the two methods is that the hedonic prices are usually fixed when using the direct method. They are potentially variable when using the indirect method.

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1 For the theoretical foundations see ROSEN (1974) and LANCASTER (1966). NELSON (2003) published a meta-analysis comparing the findings of 23 studies concerning airport noise and hedonic property values.

2 The author constructed indirect hedonic indexes for private properties based on transaction prices but modelling the communal price levels with offer prices from properties advertised in newspapers (see FAHRLAENDER 2001a and 2001b and FAHRLAENDER and HAUSMANN 2001).

For the indexation of an average property, the differences in the outcome are small, but for the indexation of a non-average object, direct indexes might be biased if structural changes exist.

Some authors stress the superiority of the indirect over the direct method since in the long term the hedonic prices should not be fixed both from a theoretical and an empirical point of view (see MAURER, PITZER and SEBASTIAN 2000, p. 4, and MURRAY and SARANTIS 1999).

The focus of this article is the construction and the discussion of indirect hedonic price indexes for condominium and single family houses in Switzerland and its regions.

Data of 38’803 transactions of condominiums as well as data of 30’870 transactions of single family houses are available for this purpose. For each transaction, information on characteristics such as location, size, standard, year of construction are available (section 2). The general setup of the hedonic models and its nationwide generalization is discussed in FAHRLAENDER (2005). Basically the same setup is used for the index construction that is the focus of this article.[3] For the price level of the location, price levels estimated for the year 2004 are used as well as yearly and quarterly dummy variables for the dynamic development of the prices on a regional level (section 3.1).

We find that the implicit prices of the characteristics change over time but the pooling over a short period should not be a major problem. Indirect indexes should be applied for the indexation of non-average properties over a longer term since direct indexes can be biased (section 3.2).

Using indirect index construction market values for a wide variety of properties all over Switzerland can be estimated over the period 1985 to 2004 and detailed analysis of the dynamics of the Swiss markets for private properties are possible (sections 3.4 and 3.5).

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[3] For the cross-section model discussed in FAHRLAENDER (2005) information concerning the condition of the property at the point of the transaction is known. For transactions before 1999, this information is not available. Therefore, the index construction is based on rather new properties and the information fort he condition therefore derivable from the construction year.

2 DATA

The analysis is based on arm's length transactions of single family houses and condominiums all over Switzerland, which took place between 1985 and 2004.[4] The data was compiled by Swiss banks and insurance companies in day-to-day business (data pool).[5] Due to the wide range of participating companies, which cover different customer segments – i.e. banks covering retail and private banking, insurance companies and the "Alternative Bank" –, and due to the size of the samples, it is believed, that the available transaction-data widely represent the Swiss market and most of its regions during the observed period.

The data pool can be divided into objects with their own identifiable site area (single family houses) and objects without their own site area (condominiums). The latter include terraced apartments and other special cases. Sale prices from arm's length transactions only are included in the samples (for the characteristics see appendix A). Special cases like ground leases, objects with depreciating easements or big development reserves are excluded, as well as properties with extreme characteristics. This is to avoid problems with leverage points. Since no geo-coordinates are available, the models are based on an estimated price level for the villages for the year 2004 (for the construction and discussion see FAHRLAENDER 2005).[6] In addition, a rather rough assessment of the location within the community (micro-location) is determined as well. To describe the property itself, details concerning size, construction year, an assessment of the standard, as well as some other information, data is available. Due to non-divisibility, site areas in Switzerland are often larger than necessary for a certain cubic content of single family houses. Using assumptions for regional differentiated planning and construction laws, out of the site areas, an excessive site area can be approximated.[7]

A total of 38'803 transactions of condominiums and of 30'870 transactions of single family houses of the period January 1985 to December 2004 are included in this analysis (see appendix B and C for the sample sizes). Centred moving samples over six quarters are

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4 Due to a very small number of observations, in some rural regions some earlier transactions from 1983 and 1984 have to be used in the cross-section model for 1985.

5 Alternative Bank Schweiz, Banque Cantonale Vaudoise, Helvetia Patria Versicherungsgesellschaft, Luzerner Kantonalbank, Thurgauer Kantonalbank, UBS, Zürcher Kantonalbank, Zurich Financial Services.

6 Out of 2'780 political communities (as of December 2004) 2'910 villages and city districts can be identified mainly in cities as well as some important villages and tourist resorts like Verbier or Crans Montana that do not represent a political community.

7 In Switzerland planning and construction laws and even measurement rules may differ from community to community or at least from Canton to Canton.

generally used for the estimation of the annual regression models. Since for some of the earlier years, only a small number of observations are available, samples over three year periods become necessary in some rural regions in the periods before 1999.

The data was compiled in the years 1999 and later, meaning that all the characteristics concern this specific period, not the time of the transaction. Therefore, only condominiums and single family houses, which at the point of the transaction were rather new, can be included in the samples.[8] Since new properties in Switzerland are generally held by their owners for a long period of time, enlargements or massive refurbishments are unlikely during quite an extended period after construction. Therefore the assumption, that the size of the properties at the point of the transaction and at the point of the compilation is identical, is reasonable. If in some cases this assumption should not hold, due to robust estimation the fits should not be affected but the variance could be increased. The same applies to other characteristics such as micro-location or standard.

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[8] All properties with an age above thirty years at the time of the transaction are excluded. Due to long renovation cycles, in the absence of a variable for the condition, variance does not increase dramatically over the first thirty years of age.

3 MODELS AND RESULTS

3.1 SETUP

The general setup is log-linear models with partwise linear and quadratic terms for the continuous variables and factors for characteristics like the micro-location and the standard. The models have the general form

$$\ln(price) = \beta_0 + f(X, \beta) + \varepsilon \,, \tag{1}$$

with a vector of the logarithms of the transaction prices ln(price), a matrix of the characteristics X, a vector of the coefficients β and a vector of the disturbances ε. The setup is in accordance with the earlier discussion of non-linearities of the continuous variables (see FAHRLAENDER 2005, p. 7-13). Since price levels have only been estimated for the year 2004, changes of the price levels become necessary for the earlier years of observation.[9] Due to lack of data, it is not possible to apply the same method as proposed (p. 13-18) but a factor can be applied estimating fixed effects β_i for 40 regions and β_j for the year and quarter of the transaction. Therefore for the period 1985 to 1999 the models are enlarged to

$$\ln(price) = \beta_0 + \beta_i + \beta_j + f(X, \beta) + \varepsilon \,. \tag{2}$$

The regions are defined in accordance with the availability of data. In the big urban areas Basel, Bern, Geneva, Lausanne or Zurich where many observations are available, regions are defined on a small level pooling only a small number of villages. In smaller urban areas such as Aarau, Lucerne, Lugano, Olten or St. Gallen a level can be generated for the urban area itself. In rural areas, where markets are thin and only little observations are available, some of the regions cover dozens of small villages.

For the period 2000 to 2004 the model is enlarged, due to the bigger number of observations. Therefore a quarterly effect can be estimated for the forty regions, hence

$$\ln(price) = \beta_0 + \beta_{ij} + f(X, \beta) + \varepsilon \,. \tag{3}$$

Due to the elimination of leverage points like farmhouses with huge site areas or some cases with obviously wrong input data, the estimations should not be susceptible for these

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9 Due to the use of the price levels of the year 2004 as well as the dummies for periods and regions, the structure of the „attractiveness of the villages“ remains constant within the regions, but varies between the regions.

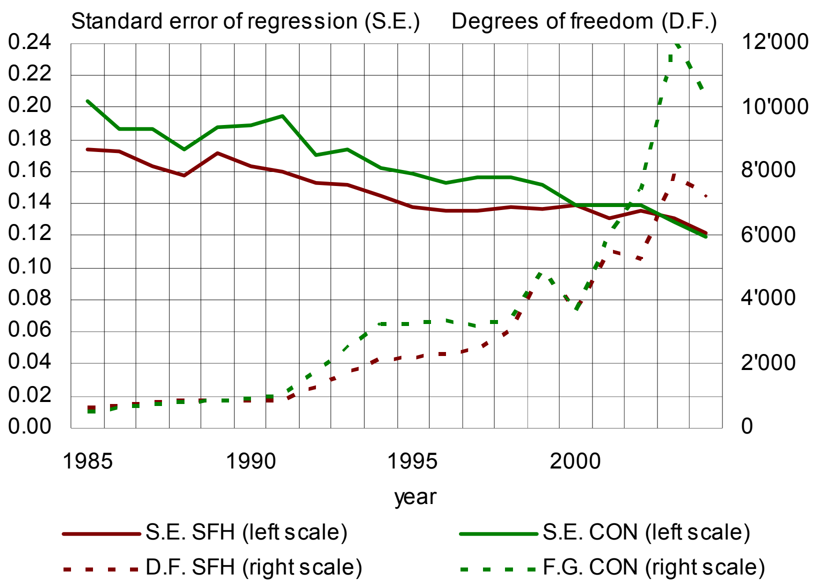
problems. However there is still an obvious risk of outlayers which especially in regions with little data available might have a very strong influence. Therefore robust techniques are applied for all estimations using Huber-M-estimators.[10]

[10] For an introduction on robust methods see for example HAMPEL ET AL. (1986), ROUSSEEUW and LEROY (2003) or RUCKSTUHL (2004). Also see appendix D.

3.2 STATISTICAL RESULTS

The analysis of the statistical results shows that the setup allows good results, despite the decrease of the standard errors (see Fig. 1). The standard error of the regression for condominiums CON (Fig. 1; upper, green line) decreased from 0.2 in the late 1980ies to 0.12 by 2004. This decrease of the standard error is mainly to be explained by the dramatic increase of the degrees of freedom during this period (Fig. 1; dotted green line). The development of the respective numbers for single family houses SFH is comparable, though the standard errors are lower during most of the observed period. But still some part of the higher standard errors in the early years might have to be explained by the fixed structure of the price levels of the villages within the regions. This assumption affects all regions since the analysis of the residuals against the regions and even the villages show no striking structures such as higher variance in larger regions or other. The constant variance across the villages speaks against the thesis of massive insufficient consideration of the price levels of the villages. It is far more likely that major refurbishments and changes in size and standard of some of the properties between the time of the transaction and the time of the compilation of the data contributed to the bigger variances in the late 1980ies.

Figure 1: Standard errors and degrees of freedom

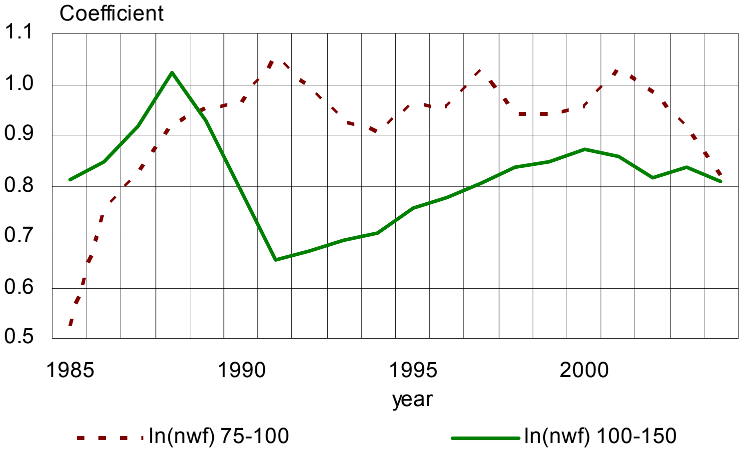


Despite a lack of information concerning the earlier transactions and because of possible variations in the structure of the price levels of the villages within the regions we believe that the chosen setup generates good results over the whole observed period.

Based on the yearly equations, the estimated coefficients show strong changes of the hedonic prices in the dynamic view, both for condominiums and single family houses. The coefficients for the dwelling (Fig. 2) and for the factor standard (Fig. 3) show strong changes over the period observed. The fact that the coefficients do not just decrease in the view back from 2004 to 1985 and the generally high significance suggest that these changes are not just artefacts because of decreasing quality of the data. However, some questions remain unanswered like for example the fact, that for the year 1985 the estimated coefficient for an excellent standard (see Fig. 2, stand=5) is smaller than the coefficient for an elevated standard (stand=4). This seems not to be very likely and is a hint for insufficient data quality.[11]

In a total view most of the coefficients in the yearly equations are highly significant different from zero and they show the expected direction. This leads us to the conclusion, that the models with its assumptions render good results.

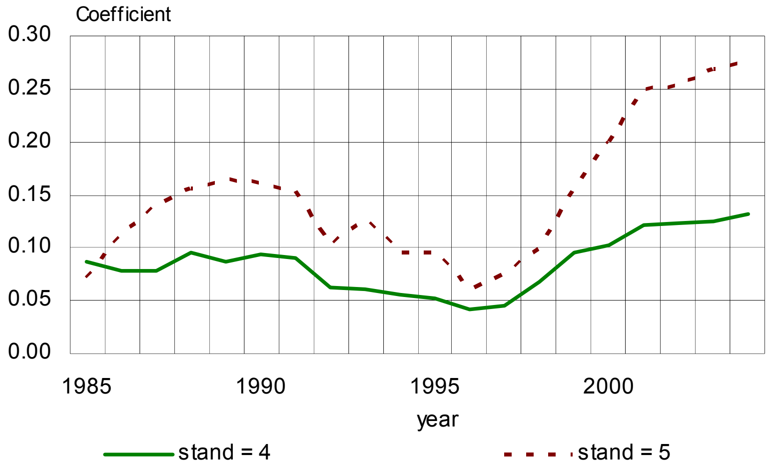
Figure 2: Selected yearly slopes for segments of ln(nwf)[12]



[11] Since the micro-location and the standard of the properties are highly correlated, this effect could be compensated by the coefficient for excellent micro-location.

[12] ln(nwf) is the logarithm of the dwelling area of condominiums. The coefficient for the dwelling area is divided into five part wise log-linear terms (see FAHRLAENDER 2005, p.9-10). ln(nwf) 75-100 is the slope for condominiums with a dwelling area of more than 75 square meters and at most 100 square meters.

Figure 3: Yearly coefficients for condition 4 and 5 for condominiums[13]



The question remains, if the observed changes of the coefficients are significant, i.e. if the structure of the model changes from a statistical point of view. This question is not to be answered just by considering the coefficients one by one. Statistically the question of structural changes can be answered using the F-statistic, the so called Chow-test (see for example GREENE 1997, p. 349ff.).[14]

The test-statistic is calculated with

$$Chow = \frac{(SSR_{12} - SSR_1 - SSR_2)/m}{(SSR_1 + SSR_2)/(N_1 + N_2 - 2m)} \approx F(m, N_1 + N_2 - m), \tag{4}$$

with SSR_{12} = sum of squares of the residuals in a pooled model, SSR_1 = sum of squares of residuals in the equation for year 1, SSR_2 = sum of squares of residuals in the equation for year 2, m = number of coefficients, and N_1 and N_2 = number of observations in the equations for years 1 and 2. This resulting test-statistic has a F-distribution with m and (N_1+N_2-m) degrees of freedom. With regard to the big number of observations, the critical value for the rejection of the hypothesis that the coefficients are equal on a 95% level is 1.32 (see for example BOHLEY 1998, p. 175).

The yearly equations can be compared pair wise in order to identify the length of a period during which structural changes are not significant, i.e. direct indexes could be estimated (see Tab. 1). The comparison of the annual equations with the equation 1998 show with the test-statistics of 0.39 and 0.03 that a pooling with the years 1997 and 1999 would not result in a

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13 The first level (omitted) is average (stand=3). Stand 4 represents an elevated standard, stand=5 a luxurious standard of the condominiums.

14 The name of the test is a reference to Chow (1960).

much larger sum of squares of the residuals. But this short view is already influenced by the fact, that one third of the samples are identical in each of the two equations. The comparison of the year 1998 with the year 1996 leads to a test-statistic of 1.98, which makes us reject the hypothesis that there is no structural change on a 95% significance level.

In general the results show that a pooling of the data over a certain period should usually not lead to a dramatic increase in the sum of squares of residuals. But for an extended period of observation, the model should be split into different equations, e.g. indirect indexes should be constructed. Results are quite similar for both condominiums and single family houses.

Table 1: Statistics of the pair wise Chow-tests for condominiums

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
1998	2.16	2.18	2.64	3.35	2.93	2.68	2.91	3.22	3.17	3.71	3.30	1.98	0.39	
1999	2.44	2.42	2.91	3.59	3.24	3.13	3.39	4.48	4.29	5.51	4.98	3.97	1.86	0.03

Using the annual equations, predictions for specific objects x^0 can be calculated and the resulting market values can be indexed. For the transformation of the estimated ln of the price $\hat{\mu}^0$ into Swiss francs CHF $\hat{y}^0$, $\hat{\mu}^0$ is usually increased by half of the estimated variance of the residuals of the equation $\hat{\sigma}^2$ to obtain the mean of the expected value (see for example GREENE 1997, p. 71). Thus

$$\hat{y}^0 = e^{\hat{\mu}^0 + \hat{\sigma}^2/2} . \tag{5}$$

The estimated variance for the predicted value $\hat{\mu}^0$ is defined with

$$\hat{\sigma}^{0^2} = \hat{\sigma}^2 + x^{0'}\left[\hat{\sigma}^2 (X'X)^{-1}\right]x^0 . \tag{6}$$

Again this variance is estimated for logarithms, the conversion into CHF is in accordance with GREENE (1997, p. 71)

$$v^0 = e^{2\hat{\mu}^0 + \sigma^{0^2}} (e^{\sigma^{0^2}} - 1) . \tag{7}$$

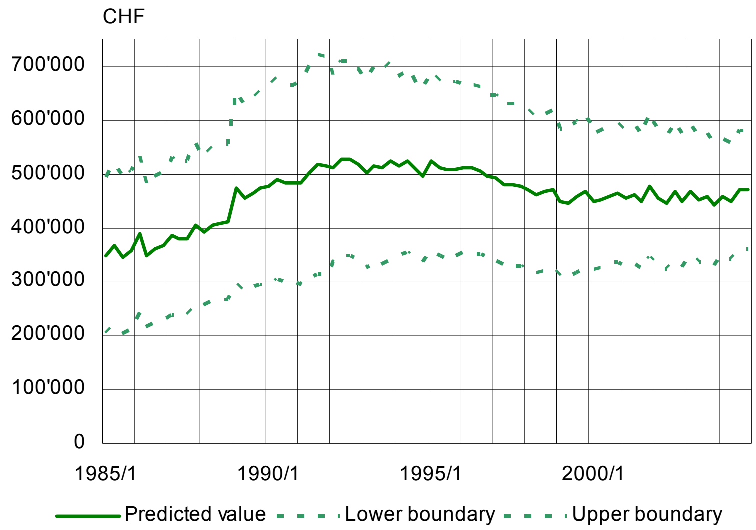
For an average condominium x^0 estimated with the model for the 4^{th} quarter 2004, a predicted value $\hat{\mu}^0 = 13.065$ results.[15] Thus $\hat{y}^0 = e^{\hat{\mu}^0 + \hat{\sigma}^2/2} =$ 472'000 CHF with a standard error of

[15] Newly built condominium with dwelling $100m^2$, average standard, good location within Aarau.

57'222 CHF which leads to a forecast interval of 360'000 CHF to 584'000 CHF on a 95% level.

Compared with many other studies, the variance of our models is quite small, and a better fit has been achieved using part wise log-linear and quadratic terms as well as regional differentiation of the relations and interaction terms (see FAHRLAENDER 2005 and appendix E and F). Although the coefficients are highly significant with small standard errors, the forecast interval in CHF is very big and does not allow to say that a – by 20% – larger but otherwise identical condominium would statistically be more expensive than the smaller one, since the forecast intervals still overlap. This is a result that intuitively does not make sense and might reflect rather data problems like insufficient information, or the relatively rough assessments of some of the qualities or others, than real variance in the prices. These large forecast intervals also affect the intervals of indexes. E.g. for the above mentioned average apartment, it is not possible to say that prices have changed during the observed period 1985 to 2004, since the forecast intervals overlap during the whole period (see Fig. 4).

Figure 4: Index for an average condominium 1st quarter 1985 to 4th quarter 2004

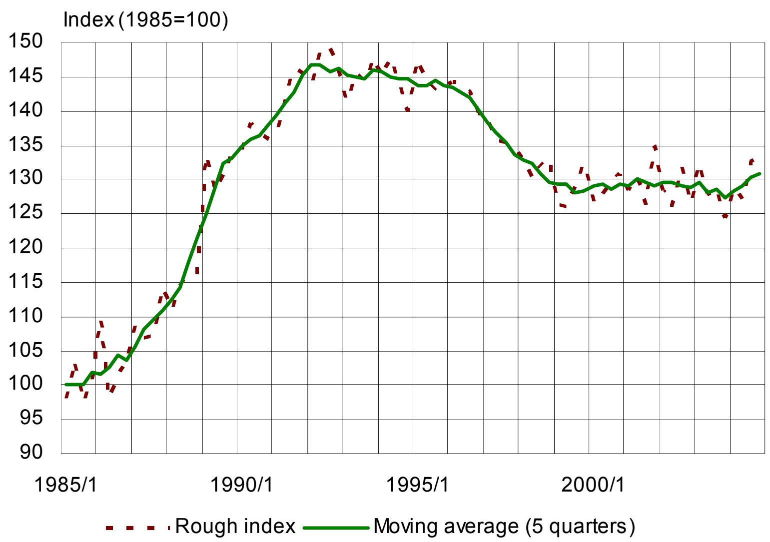


For the same reasons as for the static prediction of different properties, we believe that, although the forecast interval does not allow us to identify statistically significant differences, the index changes are still highly relevant.

3.3 SMOOTHING THE INDEXES

The quarterly indexation results in good but still quite rough indexes and the quarterly values are mainly interesting to identify turning points and other specific effects. For an analysis of the course of the indexes, the indexes could be smoothed by using annual averages. To still be able to show turning points without using unnecessary complex methods, it seems to be reasonable, to smooth the indexes using annual means or a centred moving average over the length of five quarters (see Fig. 5).

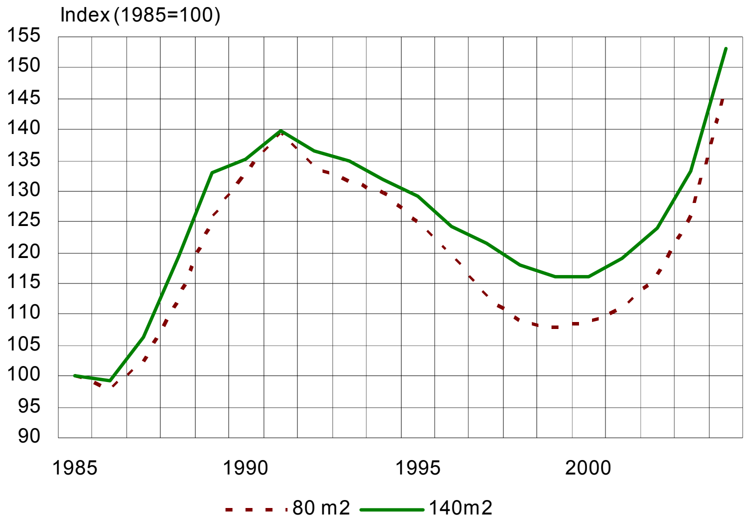
Figure 5: Smoothed index for an average condominium 1st quarter 1985 to 4th q. 2004



3.4 SPECIAL ASPECTS OF INDEXATION

Due to the changes of the coefficients over the observed periods, indexes for properties with different specification can vary (see Fig. 6).[16] The price path for two, otherwise identical, condominiums with different size show the same total change between 1985 and 1991 but the decrease of the value during the 1990ies is much stronger for the small apartment in comparison with the bigger one.

Figure 6: Indexes for otherwise identical condominiums of different size 1985 to 2004



These differences might be bigger or smaller depending on the region and the specification of the properties.

As the condition of properties without refurbishments decreases with the age, their market value decreases as well because consumers do consider the costs for the refurbishment of an old property. In this market view, for the shown example, refurbishment must not cost more than 200’000 CHF which is equivalent to an approximate annual decrease of 1% of the 2004 market value. If the estimated costs for refurbishment are higher, a buyer better goes for a new apartment or tries to negotiate the price.

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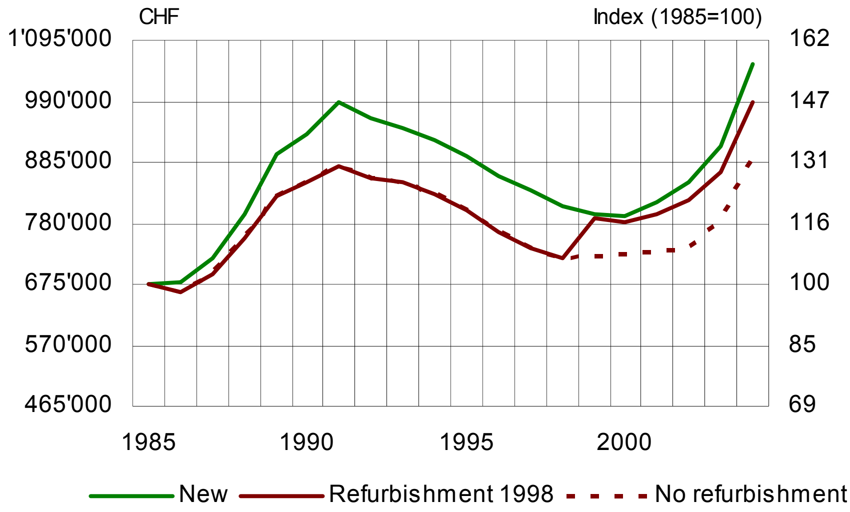
16 Condominium with average standard and good location within Küsnacht ZH, constructed in 1985.

Figure 7: Old versus new: average condominium with refurbishment in 1998



For the practical indexation of properties, it seems absolutely crucial, that refurbishments are considered (see Fig. 7) since they can alter the value of the property dramatically.

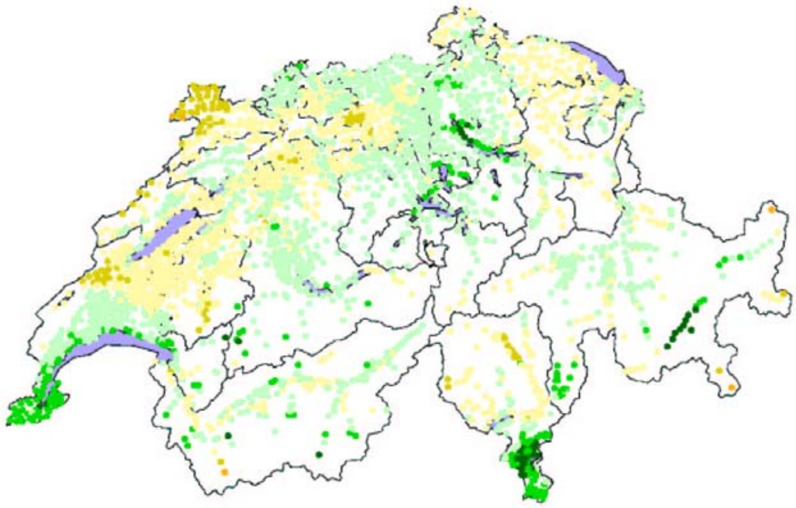
Depending on the purpose, both types of indexes are useful. To answer the question of the price path of an apartment that in 1985 was newly constructed but not refurbished, the lower, red line gives the right path and today's value. The upper, green line represents the price path of an always identical, i.e. always new, apartment – comparable to like it could be part of a consumer price index. The difference between the two price paths can be interpreted as a market view of the necessary refurbishment that can serve as a help to decide whether to invest in an old property or not.

3.5 REGIONAL DYNAMICS

The models allow the indexation of a large variety of properties with different specifications, especially with regard to the region. In principle indexes could be constructed for almost each existing private property in Switzerland. For the purpose of market analysis nationwide charts of index changes of identical objects throughout Switzerland are very useful. Figures 8 and 9 for example show the index changes between the annual means of 2001 and 2004 for standard condominiums and single family houses.

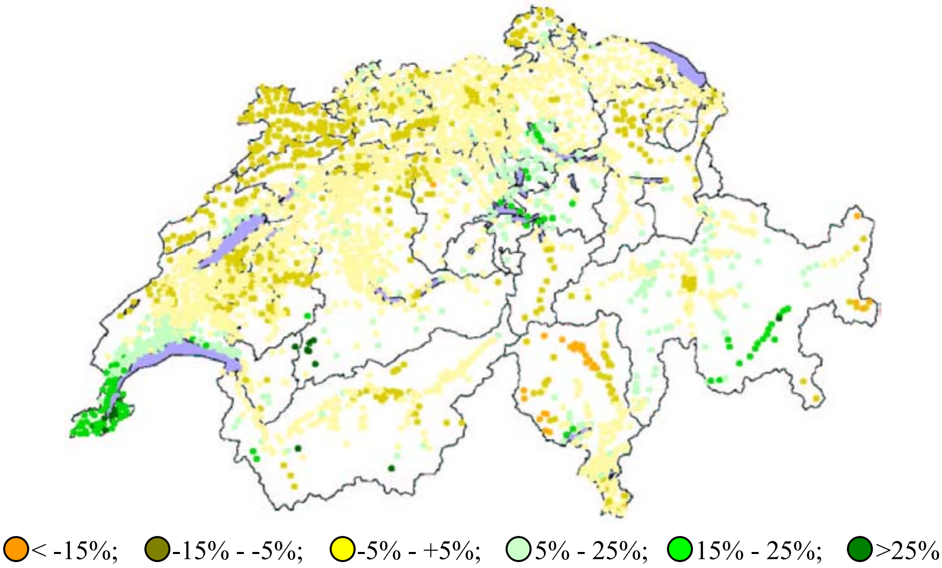
The map for condominiums (Fig. 8) shows, that prices in this market segment raised in almost all urban and tourist areas especially in the Bassin Lémanique, in the Lugano area in Southern Switzerland, in the triangle Zurich-Zug-Lucerne and in the tourist hot spots. Declines are observed in rural regions like the Jura and Southern Switzerland as well as in some smaller urban and semi-urban areas in the Lower Mainland.

Figure 8: Change in % of the values of typical condominiums 2001 to 2004



Due to large reserves of construction sites, in less urban regions, single family houses generally show quite constant prices in the observed period (see ARE 2005, p. 33ff.). Exceptions are again the Bassin Lémanique, the triangle Zurich-Zug-Lucerne as well as the Lugano area and the tourist centres where construction sites are quite rare and demand is high (Fig. 9).

Figure 9: Change in % of the values of typical single family houses 2001 to 2004



Lately, the observed raises in prices in the mentioned areas are discussed by the public and warnings of a price bubble of these regional markets are heard (see for example NZZ 2005). The combination of a general trend from rental to private properties in recent years and the historically low costs for mortgages seem to support these concerns. On the other hand, prices – in nominal terms – today are in most regions still about equal or lower to the last Swiss real estate bubble at the end of the 1980ies like figures 10 shows for condominiums and figure 11 shows for single family houses. Also for regions, where prices today are higher than during the last bubble, the question remains, if these new levels are durable or not. With regard to the change of the consumer prices of totally about 25% between 1990 and 2004 only very few villages show an increase of real property values.

Figure 10: Today's values of typical condominiums versus the values around 1990

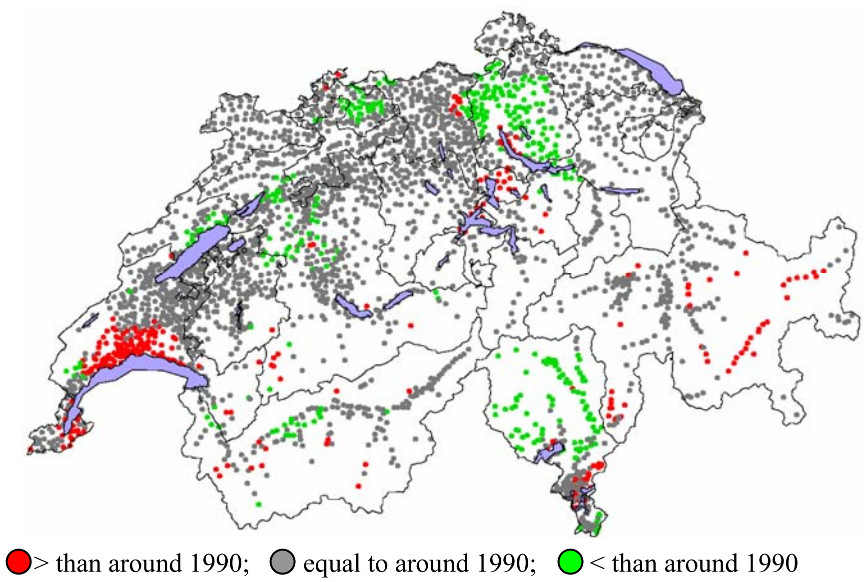
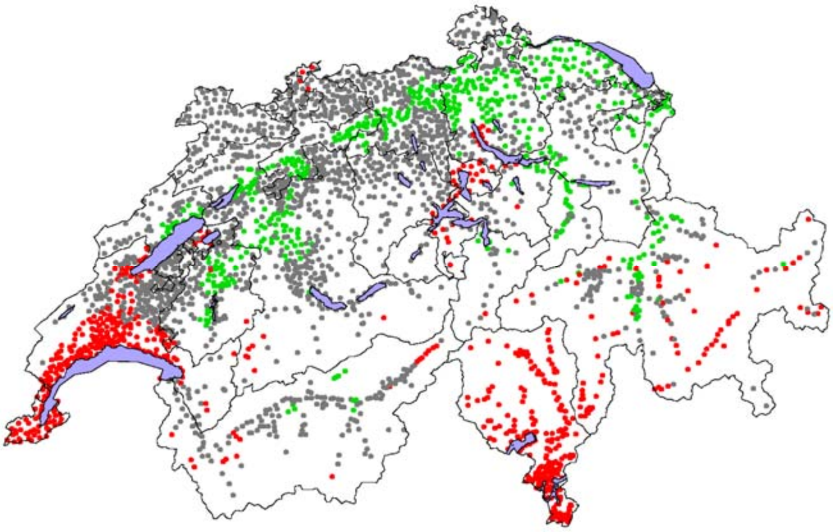


Figure 11: Today's values of typical single family houses versus the values around 1990



> than around 1990; equal to around 1990; < than around 1990

4 CONCLUDING REMARKS

In this article we show, that the direct construction of price indexes for private properties is inferior to the indirect construction, since hedonic prices usually change in a longer view. On a short view, direct indexes might be necessary due to small sample sizes and they should not lead to a mayor bias. But with regard to business cycles, structural changes in the models should be considered. Using indirectly constructed indexes, it can be demonstrated that two properties that are identical except for one characteristic show quite different price paths in the long run.

The method of the indexation depends on the purpose of the index because to estimate price changes used for a consumer price index, identical, i.e. always new properties, must be compared. If the purpose of the index is to estimate the change of the value of a specific property, changes in the condition of this property should be considered if no mayor refurbishment took place during the observed period.

From the point of view of the regional dynamics, regions show quite different price paths. In general, urban areas, where construction sites are rare, prices are much more volatile and probably also more sensitive to changes in mortgage costs and general trends than rural regions where plenty of new construction sites are available.

Regionally differentiated specific indexes are a powerful tool for real estate market analysis and due to the fact, that they are based purely on observed transactions but no other regional input data, they may serve as input for other regional models.

However, for the earlier years of the observed period, data is rather thin so further improvements of the models might be possible if more observations and more detailed data were available.

APPENDIX

A: VARIABLES

	Condominiums Median 2004	Single family houses Median 2004
Date of acquisition: *yearqu*	1st quarter 2004	2nd quarter 2004
Total sale price (in CHF, arm's length transactions)	522'000	710'000
Micro-location (factor with 5 levels): *micro*	4	4
Cubic content (in m^3 SIA 416)[17]: *volsia03*	n.a.	754
Site area (in m^2): *land*	n.a.	511
Excessive site area (in m^2): *landexc*	n.a.	100
Dwelling area (in m^2 SIA 416): *nwf*	115	n.a.
Construction year: *bauj*	2003	1996
Standard (factor with 5 levels): *stand*	4	3
Detached / attached (indicator variable): *att*	n.a.	detached
Other information (elimination criteria)	-	-

Source: DATA POOL. For details see FAHRLAENDER (2005) and WÜEST & PARTNER (2002).

17 See SIA (2003).

B: ANNUAL SAMPLES CONDOMINIUMS

Year	N	Sum transaction prices	Mean price	Median price	Stand. dev.
1985	589	CHF 207’798’071	CHF 352’798	CHF 320’000	CHF 188’783
1986	696	CHF 250’940’560	CHF 360’547	CHF 330’000	CHF 183’579
1987	794	CHF 304’110’541	CHF 383’011	CHF 350’000	CHF 190’535
1988	875	CHF 367’474’108	CHF 419’970	CHF 390’000	CHF 214’385
1989	909	CHF 421’676’323	CHF 463’890	CHF 425’000	CHF 240’165
1990	959	CHF 478’830’684	CHF 499’302	CHF 459’600	CHF 251’203
1991	1’072	CHF 548’456’792	CHF 511’620	CHF 475’000	CHF 234’344
1992	1’805	CHF 927’339’818	CHF 513’762	CHF 484’000	CHF 222’636
1993	2’527	CHF 1’324’500’563	CHF 524’140	CHF 494’546	CHF 224’848
1994	3’284	CHF 1’722’437’805	CHF 524’494	CHF 500’000	CHF 215’332
1995	3’325	CHF 1’742’158’893	CHF 523’958	CHF 500’000	CHF 208’723
1996	3’393	CHF 1’737’234’903	CHF 512’006	CHF 495’000	CHF 209’025
1997	3’227	CHF 1’631’136’249	CHF 505’465	CHF 480’000	CHF 220’547
1998	3’488	CHF 1’738’891’491	CHF 498’535	CHF 474’750	CHF 223’115
1999	4’998	CHF 2’496’621’470	CHF 499’524	CHF 475’000	CHF 220’336
2000	3’806	CHF 2’038’141’052	CHF 535’507	CHF 493’000	CHF 265’063
2001	6’235	CHF 3’463’848’722	CHF 555’549	CHF 500’000	CHF 335’437
2002	7’616	CHF 4’166’039’867	CHF 547’012	CHF 493’750	CHF 330’260
2003	12’284	CHF 6’950’105’783	CHF 565’785	CHF 500’000	CHF 338’664
2004	10’549	CHF 6’264’741’575	CHF 593’871	CHF 522’000	CHF 356’705

Source: DATA POOL.

C: ANNUAL SAMPLES SINGLE FAMILY HOUSES

Year	N	Sum transaction prices	Mean price	Median price	Stand. dev.
1985	685	CHF 428’222’211	CHF 625’142	CHF 550’000	CHF 333’822
1986	778	CHF 510’261’977	CHF 655’864	CHF 590’000	CHF 334’590
1987	856	CHF 580’874’413	CHF 678’592	CHF 604’000	CHF 333’905
1988	929	CHF 683’715’425	CHF 735’969	CHF 669’000	CHF 391’731
1989	949	CHF 756’981’398	CHF 797’662	CHF 720’000	CHF 425’113
1990	936	CHF 806’784’288	CHF 861’949	CHF 770’000	CHF 453’555
1991	952	CHF 818’970’044	CHF 860’263	CHF 775’000	CHF 397’952
1992	1’327	CHF 1’102’079’411	CHF 830’504	CHF 760’000	CHF 351’746
1993	1’766	CHF 1’461’919’776	CHF 827’814	CHF 741’000	CHF 869’993
1994	2’182	CHF 1’782’675’638	CHF 816’992	CHF 740’000	CHF 789’561
1995	2’228	CHF 1’790’867’650	CHF 803’801	CHF 720’000	CHF 783’856
1996	2’356	CHF 1’801’063’799	CHF 764’458	CHF 700’000	CHF 307’132
1997	2’554	CHF 1’902’646’189	CHF 744’967	CHF 680’000	CHF 311’529
1998	3’082	CHF 2’326’009’283	CHF 754’708	CHF 685’000	CHF 375’111
1999	4’958	CHF 3’883’722’515	CHF 783’324	CHF 710’000	CHF 383’675
2000	3’802	CHF 3’197’124’652	CHF 840’906	CHF 750’000	CHF 443’505
2001	5’683	CHF 4’891’651’184	CHF 860’752	CHF 740’000	CHF 873’783
2002	5’441	CHF 4’328’324’859	CHF 795’502	CHF 700’000	CHF 803’774
2003	8’157	CHF 6’388’221’157	CHF 783’158	CHF 700’000	CHF 389’698
2004	7’353	CHF 5’944’122’678	CHF 808’394	CHF 710’109	CHF 439’242

Source: DATA POOL.

D: ROBUST STATISTICS

In the ordinary least squares method (OLS) usually extreme outlayers are identified and removed from the sample what can already be considered as robust method (see ROUSSEEUW and LEROY 2003, p. viii). In robust regression, fitting is done by iterated re-weighted least squares using ψ-functions to control the influence of extreme observations.

The influence of an observation x on the estimator $\hat{\theta}$ in the univariate case is measured by the sensitivity curve

$$SC\left\langle x_1, x_2, \ldots x_{n-1}, \hat{\theta} \right\rangle = \frac{\hat{\theta}(x_1, x_2, \ldots x_{n-1}, x) - \hat{\theta}(x_1, x_2, \ldots x_{n-1})}{1/n} \tag{D1}$$

which for large n corresponds to the influence function (IF). The sensitivity γ*,

$$\gamma^* := \sup_x IF\left(x; \hat{\theta}; F\right), \tag{D2}$$

is the maximal influence of the observation x on the estimator $\hat{\theta}$ given a distribution *F*. For that reason the mean and the standard deviation are not robust estimators since for x → ∞, the IF as well as the γ^* are infinite. Hence the breakdown point φ_n^*,

$$\varphi_n^*\left(\hat{\theta}; x_1, x_2, \ldots, x_n\right) = \frac{m}{n}, \tag{D3}$$

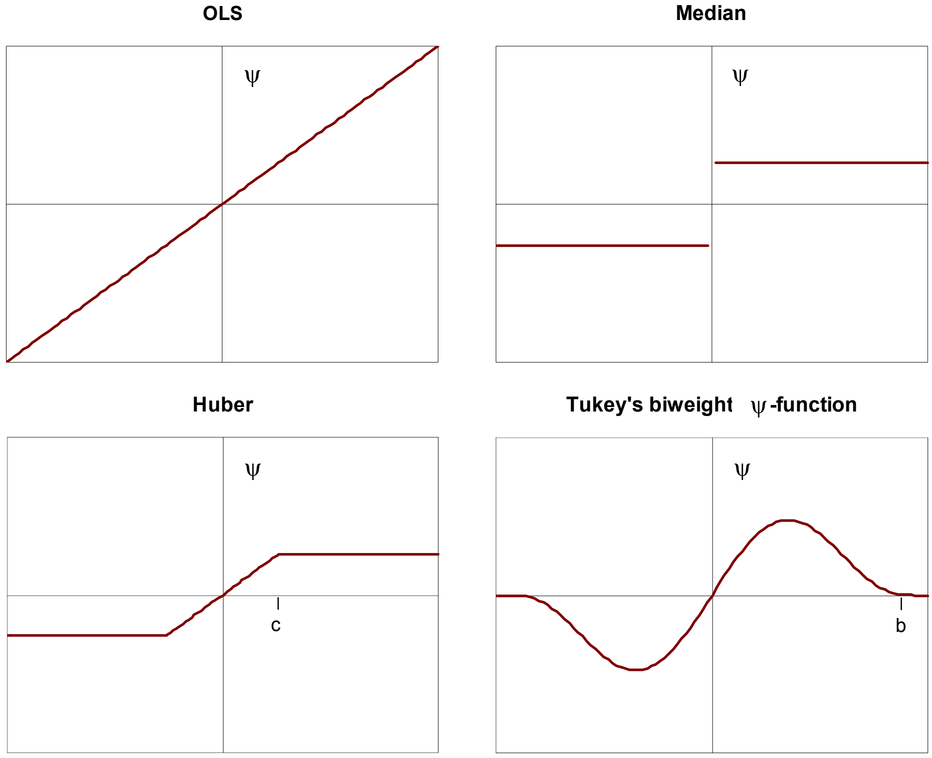
with m=maximal number of extreme observations is 0 for the mean but approx. 0.5 for example for the median. For the multivariate case, the median is not usable and therefore other methods are suggested.

Under certain conditions the p normal equations for the OLS can be written as

$$\sum_{i=1}^{n} \psi\left(\frac{y_i - \sum_{i=1}^{n} x_{ij}\beta_j}{\sigma}\right) x_{ij} = 0 \text{, with j = 1, 2, …,p} \tag{D4}$$

With y_i = target variable, x_{ij} = explanatory variables, i = observations and j = index for the explanatory variables, and the result is still a maximum-likelihood estimation. Each ψ-function, fulfilling the above equation, is called M-estimator (see Fig. D1).

Figure D1: ψ-functions of typical M-estimators



Source: RUCKSTUHL (2004, p. 9).

M-estimators are asymtotically normal distributed with covariance matrix $\sigma^2\tau C^{-1}$, with $C = 1/n\sum_i \omega_i x_i x_i'$, what up to the correction term τ (>1) corresponds with the covariance matrix of the OLS. The covariance matrix $\hat{V}$ is estimated as

$$\hat{V} = (\hat{\sigma}^2/n)\hat{\tau}\hat{C}^{-1}, \tag{D5}$$

with

$$\hat{C} = \frac{1/n\sum_{i=1}^{n}\omega_i \underline{x}_i \underline{x}_i'}{1/n\sum_{i=1}^{n}\omega_i}, \text{ with weights } \omega_i\,. \tag{D6}$$

Besides the choice of a ψ-function an estimator for the scale parameter σ is necessary. Since in outlayers are not removed from the sample but weighted, the s_{MAV}

$$s_{MAV} = median_i(|\varepsilon_i|)/0.6745 \tag{D7}$$

is recommended as asymptotic scale parameter. The correction 1/0.6745 leads to a consistent estimation of σ for exactly normal distributed residuals (SEE RUCKSTUHL 2004, p. 9).

For the R^2 ROUSSEEUW and LEROY (2003, p. 44ff) recommend

$$R^2 = 1 - \left(\frac{median|\varepsilon_i|}{\underset{i}{median}\left(\left| y_i - \underset{j}{median}(y_j) \right| \right)} \right)^2 . \tag{D8}$$

In the multivariate case, M-estimators like Huber have a breakdown point of 1/p, e.g. with 7 explanatory variables about 14 percent. Another disadvantage of M-estimators is the fact that they are usually able to identify outlayers in y-direction but usually fail with leverage points (outlayers in x-direction).

For this reason modified M-estimators (MM-estimators) using a redecending ψ-function like Tukey's biweight ψ-function of the form

$$\psi_{b_1}(u) := 1 - (1 - (\frac{u}{b_1})^2)^3 \text{, if } |u| < b_1 \text{, else 1,} \tag{D9}$$

with $b_1 = 4.685$ were proposed (YOHAI, STAHEL and ZAMAR 1991, in RUCKSTUHL 2004, p. 20, see Figure D1). The MM-estimator combines the advantages of other proposed estimators without having their disadvantages. In addition the MM-estimator has a breakdown point φ_n^* of 0.5. This estimator works with random resampling and does therefore not always produce exactly the same results. The result of a MM-estimation is again an M-estimation with the above described properties.

In this paper, generally M-estimators with Huber's ψ-function are used since in fixed effects models the resampling algorithm of the MM-estimator often leads to singularities. Where possible the MM-estimator is used to confirm the robustness of the Huber M-estimator.

E: ROBUST ESTIMATION OUTPUT FOR CONDOMINIUMS 2004[18]

	Coefficient	Standard error	Sign. level
Intercept	373.055	72.764	***
macro	0.948	0.008	***
DNWF50	-1.272	0.152	***
LNWF50	1.114	0.035	***
DNWF5075	-0.352	0.164	**
LNWF5075	0.881	0.034	***
DNWF7500	-0.056	0.179	n.s.
LNWF7500	0.820	0.036	***
LNWF0150	0.810	0.017	***
DNWF150P	-0.442	0.146	***
LNWF150P	0.899	0.024	***
bauj	-0.652	0.073	***
$bauj^2$	0.000	0.000	***
stand: 4	0.132	0.003	***
stand: 5	0.276	0.006	***
micro: 4	0.119	0.003	***
micro: 5	0.283	0.005	***
S.E. residuals	0.120		
D.F. residuals	10’345		
R^2	0.965		

Note: “.” represents a significance level of 10%, * a 5%, ** a 1% and *** a 1‰ significance level.

18 For practical reasons, the quarterly coefficients for the regions are not shown.

F: ROBUST ESTIMATION OUTPUT FOR SINGLE FAMILY HOUSES 2004[19]

	Coefficient	Standard error	Sign. level
Intercept	10.194	86.720	n.s.
macro	0.892	0.010	***
DVOL600	-1.566	0.144	***
LVOL600	0.747	0.023	***
LVOL1300	0.507	0.004	***
DVOL2300	-0.760	0.373	*
LVOL2300	0.627	0.051	***
LLA2000	0.002	0.002	n.s.
LLAE250	0.021	0.001	***
DLAE600	-0.301	0.085	***
LLAE600	0.077	0.014	***
DLAE1800	0.055	0.126	n.s.
LLAE1800	0.023	0.019	n.s.
bauj	-0.146	0.087	.
$bauj^2$	0.000	0.000	.
stand: 4	0.123	0.004	***
stand: 5	0.215	0.007	***
micro: 4	0.109	0.004	***
micro: 5	0.289	0.006	***
S.E. residuals	0.121		
D.F. residuals	7’163		
R^2	0.937		

Note: “.” represents a significance level of 10%, * a 5%, ** a 1% and *** a 1‰ significance level.

19 For practical reasons, the quarterly coefficients for the regions are not shown.

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